

## **Galveston Bay**

By Larry Handley<sup>1</sup>, Kathryn Spear<sup>1</sup>, Eleonor Taylor<sup>2</sup>, and Cindy Thatcher<sup>1</sup>

### **Background**

The Galveston Bay estuary is located on the upper Texas Gulf coast (Lester and Gonzalez, 2002). It is composed of four major sub-bays—Galveston, Trinity, East, and West Bays. It is Texas’ largest estuary on the Gulf Coast with a total area of 155,399 hectares (384,000 acres) and 1,885 km (1,171 miles) of shoreline (Burgan and Engle, 2006). The volume of the bay has increased over the past 50 years due to subsidence, dredging, and sea level rise. Outside of ship channels, the maximum depth is only 3.7 m (12 ft), with the average depth ranging from 1.2 m (4 ft) to 2.4 m (8 ft)— even shallower in areas with widespread oyster reefs (Lester and Gonzalez, 2002). The tidal range is less than 0.9 m (3 ft), but water levels and circulation are highly influenced by wind. The estuary was formed in a drowned river delta, and its bayous were once channels of the Brazos and Trinity Rivers. Today, the watersheds surrounding the Trinity and San Jacinto Rivers, along with many other smaller bayous, feed into the bay. The entire Galveston Bay watershed is 85,470 km<sup>2</sup> (33,000 miles<sup>2</sup>) large (Figure 1). Galveston Island, a 5,000 year old sand bar that lies at the western edge of the bay’s opening into the Gulf of Mexico, impedes the freshwater flow of the Trinity and San Jacinto Rivers into the Gulf, the majority of which comes from the Trinity. The Bolivar Peninsula lies at the eastern edge of the bay’s opening into the Gulf. Water flows into the Gulf at Bolivar Roads,

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<sup>1</sup>U.S. Geological Survey National Wetlands Research Center, 700 Cajundome Blvd., Lafayette, LA 70506

<sup>2</sup>Harte Research Institute for Gulf of Mexico Studies, Texas A&M University - Corpus Christi, 6300 Ocean Drive, Unit 5869, Corpus Christi, Texas 78412

Galveston Pass, between Galveston Island and Bolivar Peninsula, and at San Luis Pass, between the western side of Galveston Island and Follets Island.

Industrial and urban development around Galveston Bay is heavy, as is commercial and recreational use of the bay (Lester and Gonzalez, 2002). The western side of the bay is directly southeast of Houston and, thus, more developed and populated than the eastern side of the bay, which is primarily agricultural. Rice is the dominant crop, although production is in decline due to drought and water issues. The discovery of oil in the region and the construction of the Houston Ship Channel in the early 1900s led to extensive growth. This growth intensified during the 1970s and early 1980s. Shipping for the petrochemical and other industries is a major component of the area's economy. From Galveston Bay, one can access the Houston Ship Channel, the Gulf Intracoastal Waterway, and other navigational waterways. Heavy shipping brings with it the threats of salinity alteration, introduction of invasive species, increased erosion, and potential chemical and oil spills. The chemical industry is the largest industry in Houston, and there are approximately 7,000 oil or gas wells in the five counties surrounding Galveston Bay. The petrochemical industry in Houston is the largest in the U.S. and second largest in the world (Burgan and Engle, 2006). One-half of the country's chemicals are produced in the area, and one-third of the country's petroleum refining occurs here. The Port of Houston is the eighth largest port in the world and the second in the U.S. in total tonnage. Dredging practices are routine to maintain the waterways (Lester and Gonzalez, 2002). During the last half of the 20<sup>th</sup> century, thousands of acres of marsh were filled in private dredge and fill operations.

Galveston Bay leads Texas' fishery and environmental recreation resources (Lester and Gonzalez, 2002). Commercial landings of brown, pink, and white shrimp; blue crab; eastern oyster; black drum; flounder; sheepshead; and snapper in Galveston Bay in 1993 were worth \$11.6 million (Moulton and others, 1997). The total economic impact of commercial fishing in Galveston Bay in 1993 was \$35 million. Commercial fishing yields an economic impact of over \$400 million across the Texas coast and provides jobs for approximately 30,000 residents (Moulton and others, 1997). Recreational fishing in Galveston Bay yielded \$75-150 million in 1991, and the recreational value of the bay for all uses was \$115-200 million. Numerous bird species can be found in Galveston Bay, and birding is a growing sector of the tourism industry. Many important species of wildlife can be found in the Galveston Bay Estuary, including the endangered Kemp's ridley sea turtle.

Population growth along the Texas coast is extremely high (Lester and Gonzalez, 2002). At the 2000 census, approximately four million people lived in the five counties surrounding Galveston Bay, approximately 20 percent of which live within 3.2 km (2 miles) of the bay and its tributaries. Foreign and domestic immigration to Houston is strong. The population of the state's coastal counties increased 75 percent from 1970 to 2000 (Handley and others, 2007). From 1960 to 2000, the population increased 182 percent, from 1.6 to 4.4 million people (Burgan and Engle, 2006). By 2030, it is expected to increase another 45 percent (Handley and others, 2007). Approximately 80 percent of Texas' coastal population can be found along the upper coast of Texas, primarily around Galveston Bay. Recreational use and ecotourism are growing along with the population

around the bay. As the population grows, development around the bay and use of the bay's resources will increase.

### **Methodology Employed to Determine and Document Current Status**

Black and white and natural color aerial photography was acquired, ranging in scale from 1:20,000 to 1:65,000 (White and others, 1993). The mapping protocol consisted of stereoscopic photointerpretation, cartographic transfer, and digitization in accordance with strict mapping standards and conventions. Other important aspects of the protocol included the use of the Cowardin Classification System (Cowardin et al., 1979), groundtruthing, quality control, and peer review. Land, water, and areas where emergent wetlands were present were included on the maps. The information derived from the photography was subsequently transferred using a zoom transfer scope onto a stable medium overlaying U.S. Geological Survey (USGS) 7.5-minute, 1:24,000-scale quadrangle basemaps. The groundtruthing phase was conducted to characterize wetland plant communities and compare wetland plant communities in the field with corresponding signatures on the aerial photographs. Draft maps were peer reviewed. All comments received were incorporated into the final maps prepared and delivered.

### **Methodology Employed to Analyze Historical Trends**

Historical emergent wetland trends were analyzed by comparing changes in total areal coverage of emergent wetland habitat along a time sequence. Comparisons were made among data sums of emergent wetland coverage for 1956, 1979, and 1992. Maps of emergent wetland distribution for these years were studied to determine the location of major changes of coverage. The 1956 data were derived from USDA 1:20,000 scale,

black and white aerial photography. The 1979 and 1992 data were derived from NASA 1:65,000 scale, color infrared aerial photography.

## Status and Trends

Emergent wetland monitoring during 1956, 1979, and 1992 (Figures 2-4) illustrates the coverage change of emergent wetland habitat in Galveston Bay (Table 1). Galveston Bay lost 10,560 hectares (26,094 acres), or 17.3%, of its emergent wetlands between 1956 and 1979; and it gained 8,212 hectares (20,292 acres), or 13.4%, of its emergent wetlands between 1979 and 1992. During the complete 37-yr time period this study encompasses, Galveston Bay lost 2,348 hectares (5,802 acres), or 3.8%, of emergent wetland habitat.

**Table 1. Emergent wetland acreage in Galveston Bay for 1956, 1979, and 1992.**

Emergent Wetland Type	1956		1979		1992		Total Change 1956- 1992	
	Hectares	Acres	Hectares	Acres	Hectares	Acres	Hectares	Acres
Estuarine	46,142	114,020	40,269	99,507	30,900	76,355	-15,243	-37,665
Palustrine	14,938	36,914	10,252	25,333	27,833	68,777	12,894	31,863
Total	61,081	150,934	50,521	124,840	58,733	145,132	-2,348	-5,802

Between 1956 and 1979, Galveston Bay lost 5,873 hectares (14,513 acres), or 12.7%, of salt marsh. A loss of 9,369 hectares (23,152 acres), or 20.3%, of salt marsh occurred between 1979 and 1992. A total of 15,243 hectares (37,665 acres), or 33.0%, of salt marsh was lost during the entire 37-yr study period.

Galveston Bay lost 4,687 hectares (11,581 acres), or 31.4%, of coastal fresh marsh between 1956 and 1979. A gain of 17,581 hectares (43,443 acres), or 117.7%, of

fresh marsh occurred between 1979 and 1992. A total of 12,894 hectares (31,863 acres), or 86.3%, of coastal fresh marsh was gained in Galveston Bay during the entire 37-yr study period.

### **Causes of Change**

Subsidence has been a major factor in wetland loss in Galveston Bay (White and others, 1993; Handley and others, 2007). Other contributing factors to wetland loss in Galveston Bay in the past 60 years have been industrial development, urbanization, navigation channels, flood control and other water projects such as upstream impoundments, drainage and filling of wetlands, and agricultural runoff (White and others, 1993; Johnston and others, 1995). Pollution and natural events such as hurricanes have also caused alterations to natural ecosystems in Galveston Bay (Handley and others, 2007). Wetland loss specifically has been caused by relative sea-level rise (a combination of land subsidence and sea level rise; White and others, 1993); land use conversion (including conversion to drainage ditches, cropland, pastureland, urban areas, and oil and gas production); dredge-and-fill projects; and isolation projects (large-scale projects such as hunting areas, cooling ponds, salt water barriers, and flood control that have caused large areas to be isolated from the bay) (Lester and Gonzalez, 2002). A significant increase in palustrine wetlands and decrease in estuarine wetlands occurred along the eastern shore of Galveston Bay in 1992 because of the addition of weirs that resulted in altered water management and the conversion of estuarine to palustrine emergent wetland habitat. Habitat loss—including that of wetlands—tops the Galveston Bay Priority Problems List (Lester and Gonzalez, 2002). Coastal prairie freshwater wetlands have been allowed to be developed without a permit or mitigation since 2001; as Houston

grows, this has resulted in substantial habitat loss (Lester and Gonzalez, 2002). The proportional rate of wetland loss in Galveston Bay is higher than the national rate.

A variety of factors contributes to coastal degradation in the Galveston Bay estuary. Subsidence resulting from groundwater withdrawal and conversion to upland range are among the top causes of wetland loss. Over 9,428 km<sup>2</sup> (3,640 miles<sup>2</sup>) of land in the Houston-Galveston area have subsided 0.3 m (1 ft) or more. Shoreline management practices, such as bulkheads, docks, and revetments, contribute to erosion, high turbidity, habitat loss, and pollution. Nonpoint source pollution is the major water quality problem in Galveston Bay. Sewage, industrial waste, and other toxic and hazardous substances have contaminated the water, sediment, and living resources in some areas via runoff, dumping, leakage, and spills. Contamination, habitat loss, and intensive harvesting have caused the decline of some populations of birds and aquatic organisms. The most common cause of fish kills in Galveston Bay is low dissolved oxygen. Some species of wildlife, such as the striped bass and diamondback terrapin, have either disappeared or declined drastically since the mid-1800s. Great blue heron abundance declined during the last quarter of the 20<sup>th</sup> century, along with tricolored herons and roseate spoonbills. The National Coastal Assessment gave Galveston Bay a composite rating of fair, based on a water quality index of poor, a sediment quality index of fair to poor, a benthic index of fair, and a fish tissue contaminants index of good to fair (Burgan and Engle, 2006). Hazardous chemicals present in the sediment of the Houston Ship Channel, toxic blooms and red tides, invasive species, and competition for fresh water resources are other areas of concern in the estuary.

## **Mapping and Monitoring Needs**

The most comprehensive wetlands delineation datasets for Galveston Bay are: 1) the National Wetland Inventory (NWI); 2) NOAA's Coastal Change Analysis Program (C-CAP); 3) the Status and Trends of Wetlands and Aquatic Habitats project (White and others, 2004); and 4) USGS' Delineation of Marsh Types of the Texas Coast (Enwright and others, 2014). The NWI dataset maps the areal extent of wetlands and surface waters as defined by Cowardin and others (1979) wetland classification. NWI data coverage is available for Galveston Bay, and some sections were most recently updated in 2009 using 2006 sub-meter true color and 2004 NAIP color-infrared imagery for areas in McFaddin and Brazoria National Wildlife Refuges (U.S. Fish & Wildlife Service, 2009). The scale of NWI data varies from 1:10,000-1:24,000. The NOAA C-CAP classification is derived from Landsat TM scenes collected in 2010-2011 for Texas and Louisiana and analyzed according to a standard land cover classification protocol (NOAA, 2014). The resolution of the dataset is 30-m and includes developed land, palustrine and estuarine wetlands, palustrine and estuarine aquatic beds, and water classes. Additional C-CAP coverage for Galveston Bay is available for 1996, 2001, and 2006. A more detailed wetland delineation has been completed for the Texas General Land Office as part of the "Status and Trends of Wetlands and Aquatic Habitats of Galveston and Christmas Bays" project (White and others, 2004). Habitat delineation was done using 2002 1-m resolution color-infrared aerial imagery and mapped at a 1:6,000 scale. Wetlands were mapped following the classification by Cowardin et al. (1979). Although the scale of this dataset is well-suited for many applications; its geographic extent is limited, only covering the barrier island system protecting Christmas, and West and East Galveston Bays. The three



wetlands delineation datasets offer different spatial and temporal resolutions that may be appropriate for regional studies. However, there is still a need for site-scale (~ 1:6000) wetlands mapping across Galveston Bay with higher temporal resolution to better track, document, and understand wetlands change patterns.

### **Restoration and Enhancement Opportunities**

Earlier in 2013, the Texas General Land Office held a series of meetings along the coast to develop a list of key coastal issues and obtain feedback on potential projects (Gibeaut and others, 2014). The Texas coast was divided into four regions. Each region developed a list of potential projects that was reviewed by a Technical Advisory Committee (TAC). Feedback provided by the TAC for Region 1 (Orange, Jefferson, Chambers, Harris, Galveston, and Brazoria counties) indicated Gulf beach/dune erosion, wetlands/habitat loss, and flooding and storm surge as the top three priorities and issues of concern (Gibeaut and others, 2014). The reviewed proposed projects directly benefiting emergent wetlands in the region included conservation easements, shoreline protection and restoration by dredged material placement, and shoreline and marsh restoration efforts (Gibeaut and others, 2014).

Another restoration opportunity involves the construction of living shorelines as an alternative to hard structures for shoreline erosion control and management. A living shoreline is a structure that protects and/or stabilizes a shoreline using plants, shells, sand, soil, rocks, organic materials, and limited human-made components. If successful, living shorelines can become fully-developed wetlands. The Galveston Bay Foundation runs a “Living Shorelines” program as part of their conservation efforts. In cooperation with

various partners, the Galveston Bay Foundation offers assistance and guidance to private landowners with the design, permitting, and identifying funding sources for their living shoreline project (Galveston Bay Foundation, 2014). Although living shoreline projects are small, the cumulative benefits of added wetland acreage over a large area may be significant over time (Galveston Bay Foundation, 2014).

Marsh loss in Galveston Bay has resulted from the effects of sea level rise, subsidence, wave erosion, and sediment supply deprivation (Ravens and others, 2009). Coastal subsidence due to groundwater extraction has been a prominent factor in marsh loss, but its influence has been minimized as extraction activities have dwindled over the past decade (Ravens and others, 2009; White and others, 2004). Deficient sediment supply and wave erosion, however, are still contributing factors. In their study, Ravens and others (2009) found that the impact of wave-induced erosion on marsh loss in Galveston Bay is relatively small compared to sediment supply starvation caused by past river damming. Thus, recommendations for future salt marsh restoration projects in the area point at the inclusion of design components to enhance sediment supply, rather than focusing on wave protection alone (Ravens and others, 2009).

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Figure 1. Watershed for Galveston Bay.

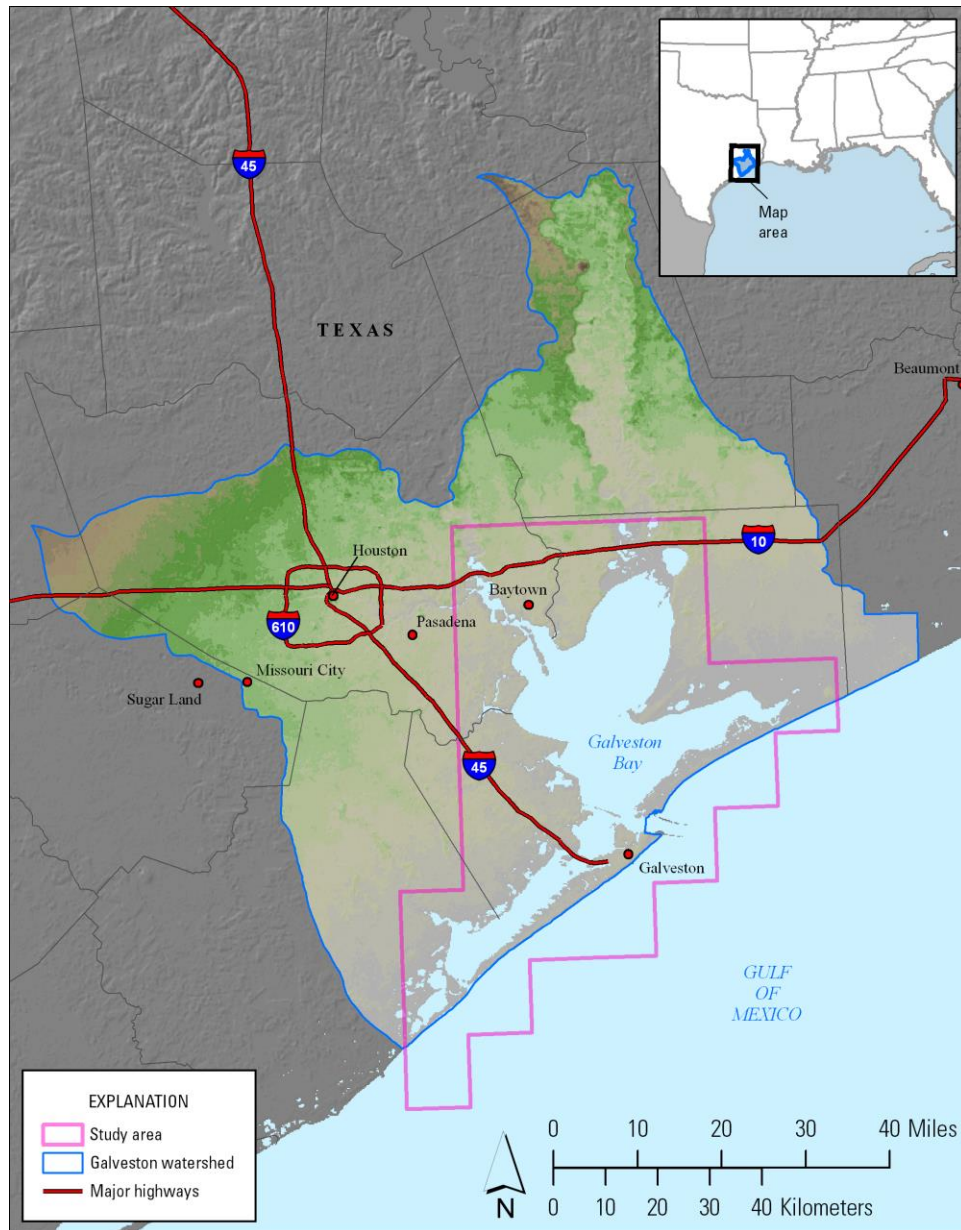


Figure 2. Distribution of emergent wetlands in Galveston Bay, 1956.

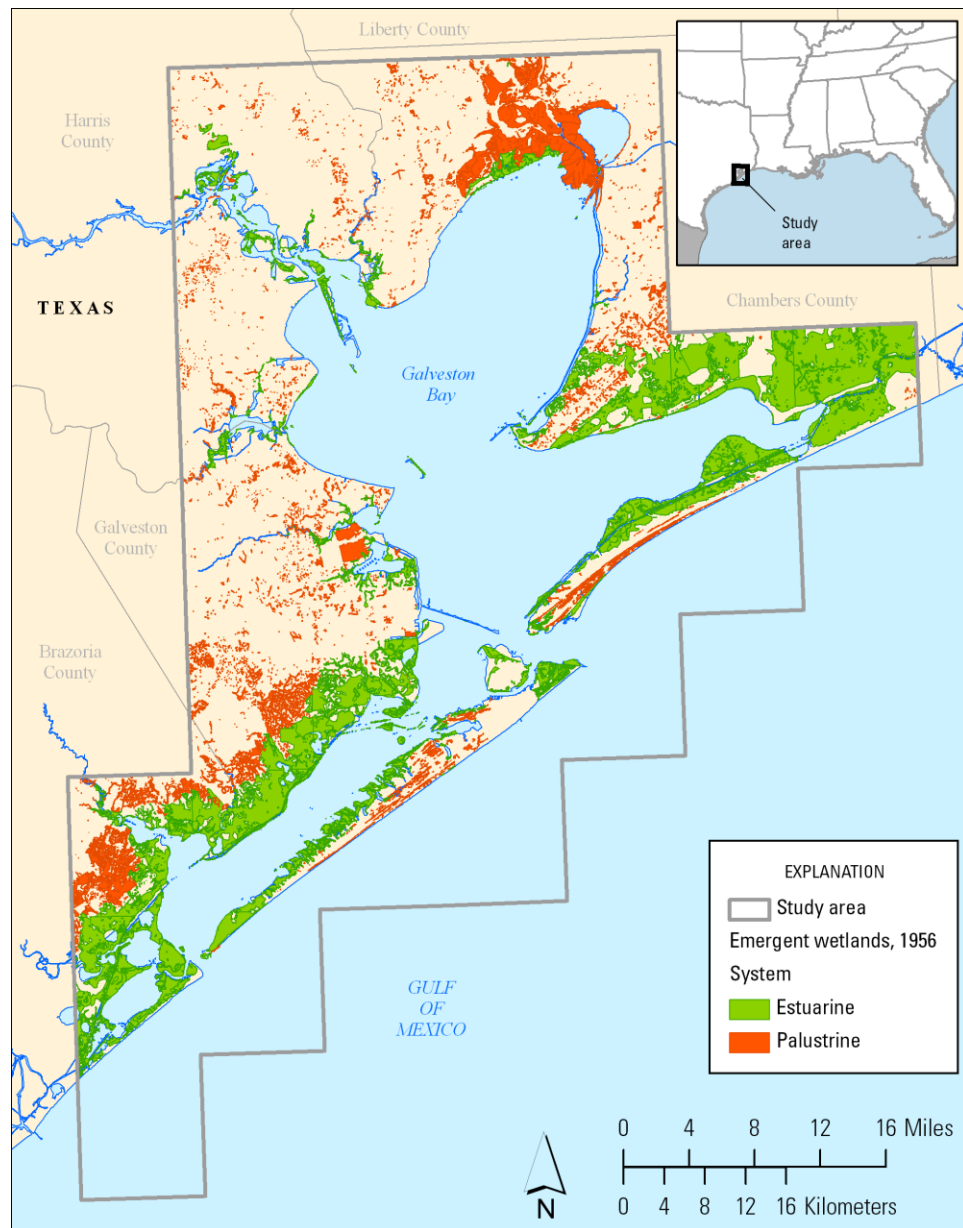


Figure 3. Distribution of emergent wetlands in Galveston Bay, 1979.

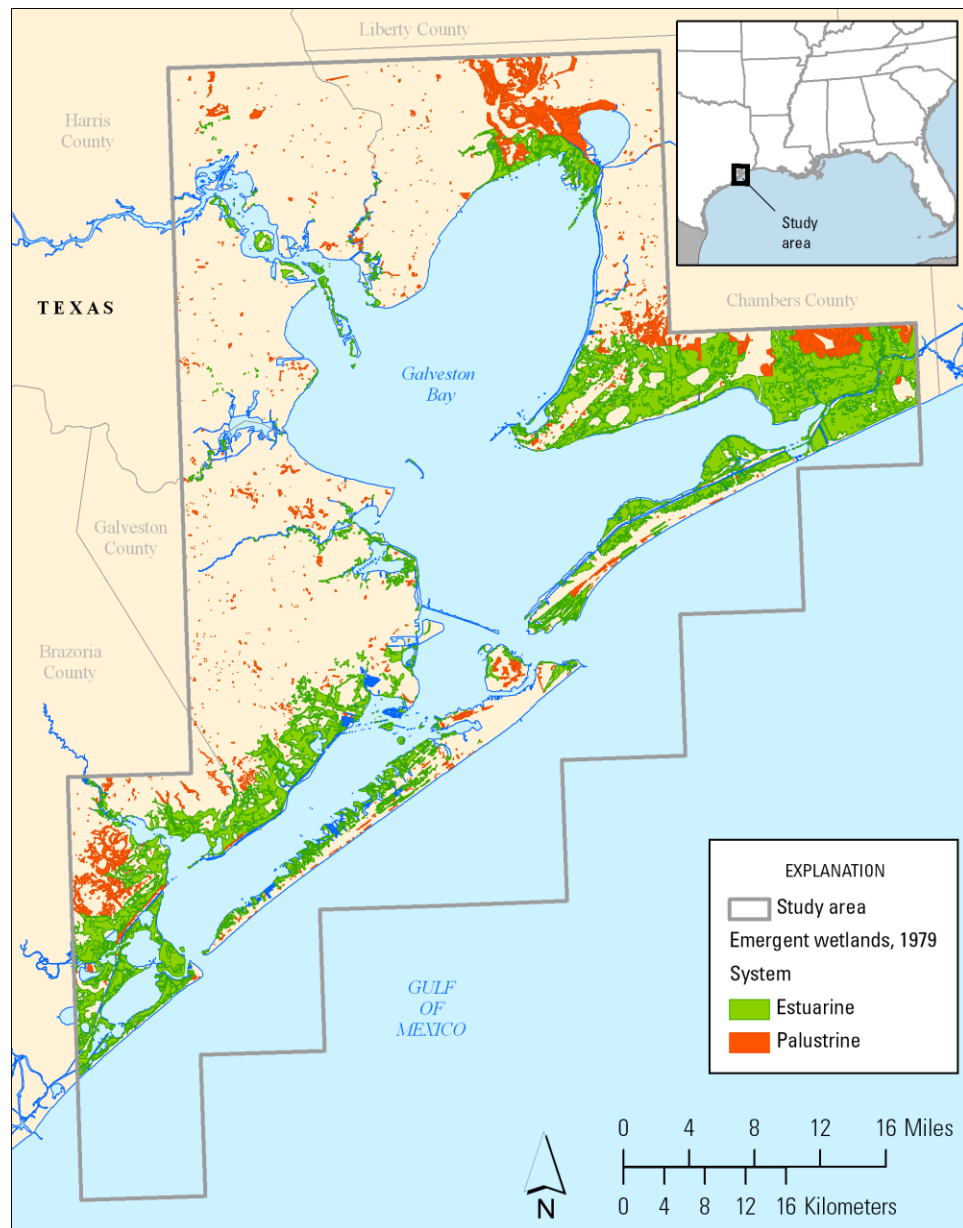


Figure 4. Distribution of emergent wetlands in Galveston Bay, 1992.

